

3D HELIOSPHERIC RECONSTRUCTIONS FROM THE SECCHI WHITE LIGHT CORONAGRAPHS ONBOARD STEREO: RESULTS FROM THE EARLY RECONSTRUCTIONS

**J.W. Cook, J.S. Newmark (Naval Research
Laboratory), P.A. Reiser, P.C. Crane
(Interferometrics), A. Yahil, T. Gosnell, and R. Puetter
(Pixon LLC)**

The twin STEREO spacecraft will carry onboard the SECCHI (Sun-Earth Connection Coronal and Heliospheric Investigation) experiment, consisting of an EUVI disk imager and three white light coronagraphs on each spacecraft. At NRL we are investigating the tomographic electron density reconstructions, and their limitations, which are achievable from just two viewpoints using the coronagraph observations. We employ the PIXON technique for reconstruction. In this presentation we discuss results from early reconstructions.

We have started with simple geometrical volumes of constant $1 \times 10^8 \text{ cm}^{-3}$ electron number density: cylinders (toy coronal polar plumes), and hemispherical shells with a main axis along a line to Sun center (toy coronal mass ejections). We have results for all model problems with $64 \times 64 \times 64$ resolution volumes, and selected problems with $128 \times 128 \times 128$ resolution. Our model coronagraph observes to $15 R_{\odot}$, with an occulter extending to $1.3 R_{\odot}$. We render from the starting known electron density distribution within a 3D volume (the input IMAGE) a synthetic white light input DATA 2D picture, in radial and tangential polarizations. We use two viewpoints in the ecliptic plane, at 0° (behind B spacecraft) and 37° (ahead A spacecraft), appropriate for early in the STEREO mission, or three

viewpoints, at -37° (B), 0° (Earth), and 37° (A). From these input synthetic observations, our PIXON technique produces an electron density reconstruction (3D output IMAGE), using the fewest PIXON elements, that renders 2D output DATA pictures which best agree with the 2D input DATA pictures. We discuss the following test problems, illustrating the degree of agreement of the PIXON output IMAGE reconstructions with the known starting input IMAGE model electron density distributions, and of the rendered input and output DATA pictures. We are particularly interested in the limitations present when only two viewpoints are available. The test problems are:

1. Plumes, finite geometry, 2 viewpoints, polarization
2. Plumes, *infinite* geometry, 2 viewpoints, polarization
3. Plumes, finite geometry, 3 *viewpoints*, polarization
4. Plumes, finite geometry, 2 viewpoints, *brightness*
5. CME, finite geometry, 2 viewpoints, polarization
6. CME, *infinite* geometry, 2 viewpoints, polarization
7. CME, finite geometry, 3 *viewpoints*, polarization
8. CME, finite geometry, 2 viewpoints, *brightness*
- 9-13. CME, finite geometry, 2 viewpoints, polarization, *CME at angles to the plane of the sky of 60° , 45° , 0° , -45° , and -60°* . We illustrate that reconstructions are possible for structures far from the plane of the sky. The fundamental consideration is the signal-to-noise level of the input DATA observations used. (In interpreting our results, to express DATA intensities in terms of B/B_0 , for our choice of problem numerical values, $B_0 = 5.6 \times 10^{20} \text{ ph cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$. Our test objects are unrealistically bright, both from the assumed electron density and from the choice of solar spectral parameters employed. We are still learning!)

We have for each test problem a group of diagnostic figures to evaluate the reconstruction. We illustrate below selected diagnostic figures for test problems 1 and 5, the standard plumes and CME problems, at $128 \times 128 \times 128$ resolution. For problems 1 and 5 we show:

DATA rendered from the input and PIXON output IMAGE 3D electron

density distributions. Look for differences;

The above rendered synthetic DATA placed in the model CCD field-of-view;

Two pictorial quantitative representations of the difference between the input and PIXON output DATA;

A visualization of the input and PIXON output IMAGE 3D electron density distributions along four representative viewpoints. Notice the differences viewed from the +z axis, where the PIXON reconstruction is least constrained by the input DATA;

Two histogram representations of the quantitative difference between the input and PIXON output DATA;

Two histogram representations of the quantitative difference between the input and PIXON output IMAGE 3D electron density distributions.

We have with us the diagnostic figures for all of the problems, and will use them in individual discussions about the results from our series of test problems. We compare reconstructions using realistic, finite geometry lines-of-sight vs. infinite geometry with all lines-of-sight parallel (Sun at infinity); reconstructions using two viewpoints vs. an extra third viewpoint; and reconstructions using tangential and radial polarizations vs. brightness alone. With only two viewpoints it is possible to produce "shadow" reconstructed artifacts of the features which were present in the starting model volume, via the symmetry of the two viewpoint angles. These artifacts are partly removed with the addition of the third viewpoint to the reconstruction.

We will make selected reconstructions available to the STEREO community as test problems. We solicit for the SECCHI effort the contributions of outside researchers to this very difficult problem. The test problems, with information describing the test data and model parameters used, can be found at <http://stereo.nrl.navy.mil> by following the "3D R & V" link.

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